

Research Summary

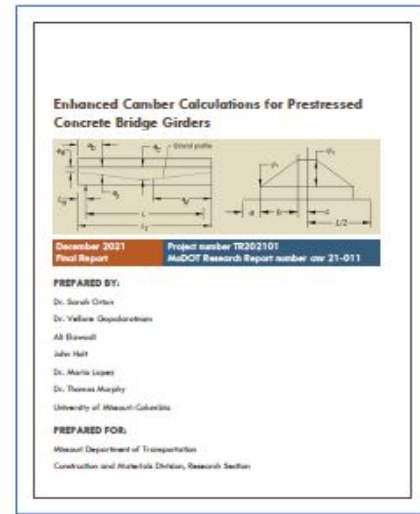
Enhanced Camber Calculations for Prestressed Concrete Bridge Girders

The objective of this study was to develop accurate prestressed girder camber calculations and validate them with available data. Accurate bridge camber in prestressed concrete girders is a critical design component in the ride, appearance, maintenance requirements, slab placement, and overall life of a concrete bridge superstructure.

A literature review found several previous studies that have highlighted the difficulties in predicting initial and long-term camber. Even with improvements to equations, accuracy was at best in the $\pm 15\%$ range. The primary causes of camber error were concrete compressive strength, concrete modulus, temperature effects, creep and shrinkage parameters, support geometry, and camber measurement errors.

Data from 189 girders with initial camber and 33 girders with later camber measurements before hauling were analyzed to evaluate the accuracy of the camber calculation procedure. In addition, field measurements were conducted on four girders, including material characterization tests for concrete strength gain with time, modulus, and creep.

The current camber measurement showed an average under-prediction of the camber by about 23% with a RMSE of 0.81 in. and average error of 35%. The camber measurement method in



two precast plants were compared. It was found that the self-weight of the string line used to measure camber caused a significant sag and led to larger than actual camber measurements.

A systematic look at the parameters affecting the accuracy of the initial and long-term camber predictions was undertaken. The parameters of overhang length, concrete modulus, concrete strength/age, temperatures, prestressing force, section properties, temperature during curing, concrete density, strand eccentricity, creep, shrinkage, humidity, and long-term analysis method were systematically investigated.

“Accurate bridge camber in prestressed concrete girders is a critical design component in the ride, appearance, maintenance requirements, slab placement, and overall life of a concrete bridge superstructure.”

The investigation found that the length of the overhang (distance past temporary supports) does affect camber. A change in overhang length from 0 ft. to 4 ft. can cause a change in camber of about 20% (average change based on girder data set). Analysis equations used in PGSuper can be used to include the effect of overhang in the initial camber. Concrete modulus equations from different sources only changed the camber

prediction by about 4%. Using the measured compressive strength, decreases the trendline slope of the measured to predicted camber by 10%. Increased temperatures during curing can temporarily reduce prestress forces and reduce camber by about 12%. Daily temperature changes cause a thermal gradient in the girder and can increase camber by 25% with a 25 °F temperature change. The effect of temperature should be considered in the camber results. In order to mitigate the effect of temperature, camber can be measured at least 72 hours after form release, and in the morning (Tadros 2015). Other factors investigated did not significantly change the camber prediction. The project also found that procedures and tolerances for the measurement of camber and location of temporary supports at prestress girder plants are needed.

Modifications to the camber calculation reduced the underprediction of camber to less than 4% on average (when sag in the string line measurement was accounted for) and decreased the RMSE from 0.81 in. to 0.30 in. and the average error from 35% to 20%. This yielded predictions that were in most cases within $\pm 25\%$ of the measured camber. The proposed method was implemented into a computer spreadsheet for easy calculation.



Figure 1: Concrete creep test setup

Project Information

PROJECT NAME: TR202101— Enhanced Camber Calculations for Prestressed Concrete Bridge Girders

PROJECT START/END DATE: September 2020-November 2021

PROJECT COST: \$79,999

LEAD CONTRACTOR: University of Missouri-Columbia

PRINCIPAL INVESTIGATOR: Dr. Sarah Orton

REPORT NAME: Enhanced Camber Calculations for Prestressed Concrete Bridge Girders

REPORT NUMBER: cmr 21-011

REPORT DATE: December 2021

Project Manager



CONTACT INFORMATION:

Jennifer Harper
Research Director
Missouri Dept. of Transportation
1617 Missouri Blvd.
Jefferson City, MO 65109
(573) 526-3636
Jennifer.Harper@modot.mo.gov